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OPERATING MANUAL - J-BAND FREQUENCY TRANSLATOR AND MICROSCAN RECEIVER PROCESSOR

Stanford Research Institute
Menlo Park, California

March 1975

STANFORD RESEARCH INSTITUTE
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Richard E. Bessey John E. Winter

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Prepared Under

U.S. Army Electronics Command
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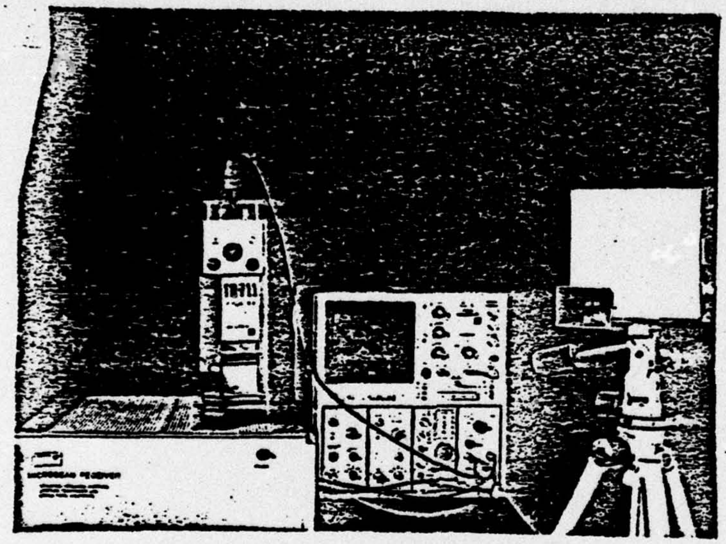

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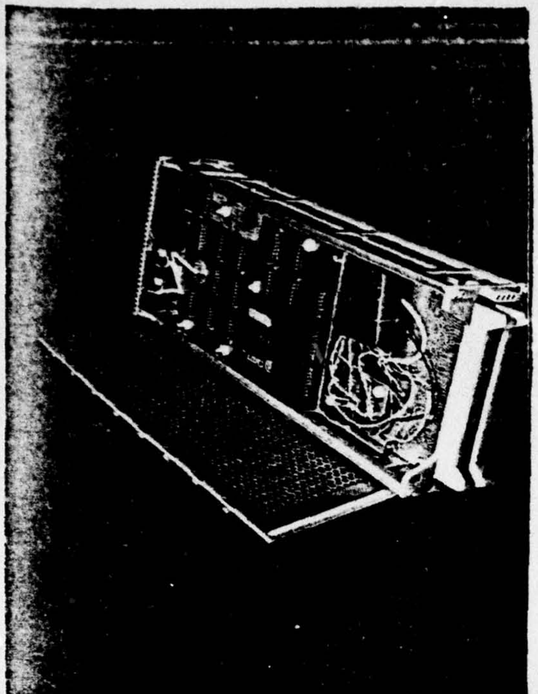

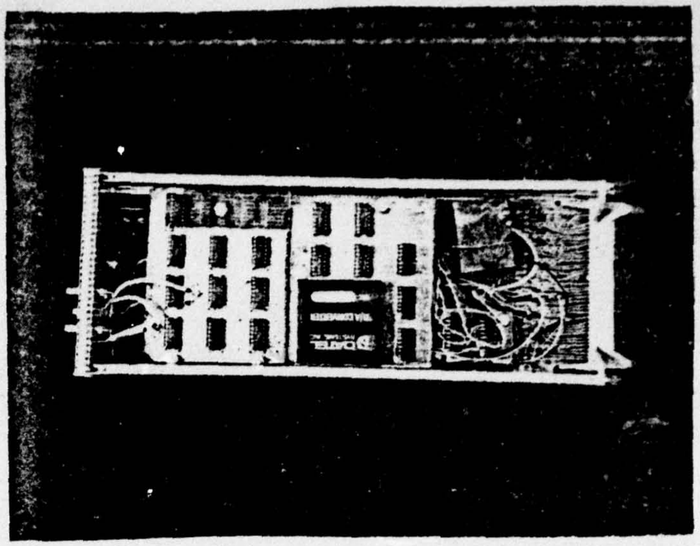

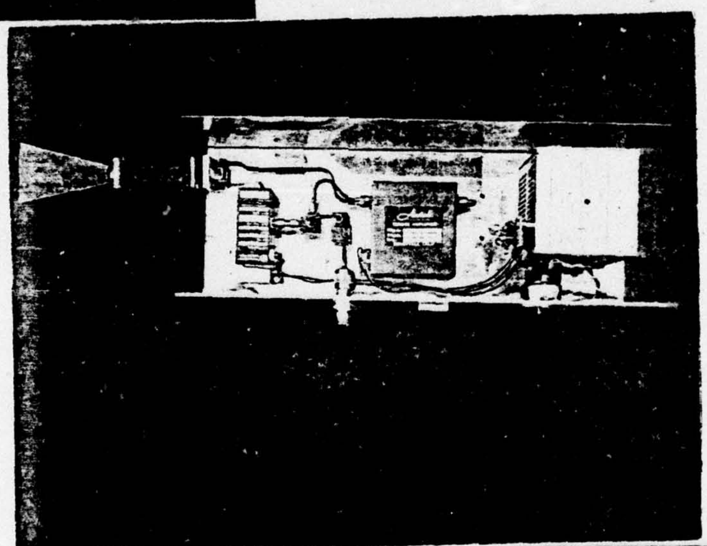

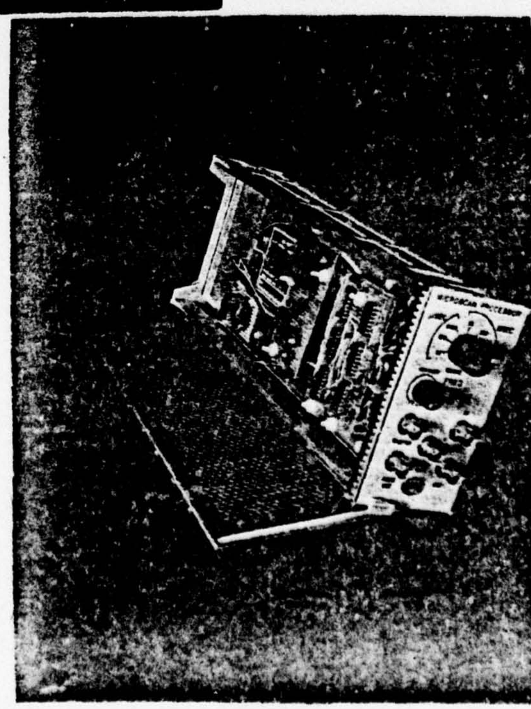

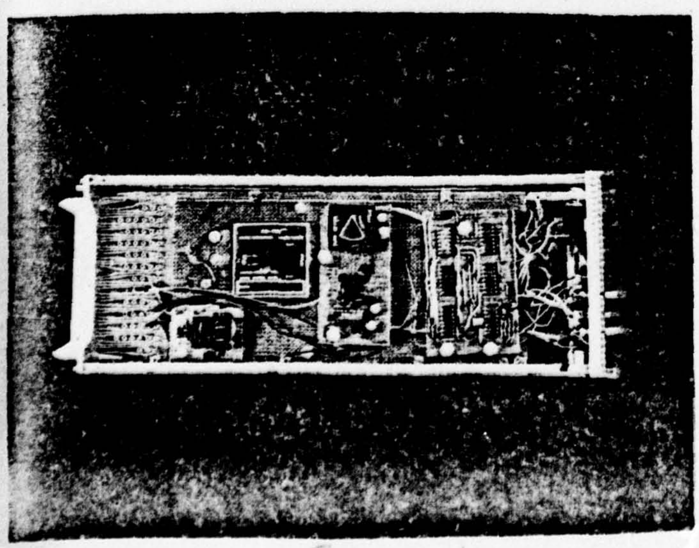

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J-Band Frequency Translator and Microscan Receiver Processor

I. Introduction

The equipment supplied enables an observer to determine the frequency and pulse-timing characteristics of a signal in the 16.5 to 17.0 GHz band. A tripod-mounted translator receives the RF signal and translates 16.5 - 17.0 GHz down to 5.0 - 5.5 GHz. A horn antenna on the translator provides 18 dB gain over an isotropic antenna, and a bandpass filter mounted behind the antenna limits coverage to the band specified. Two 23 dB gain, 5.6 dB noise figure tunnel-diode amplifiers in the translator may be connected or disconnected at the operator's discretion, allowing a wide dynamic range or input signal levels to be handled.

The IF output of the translator is fed to a 5.0 to 6.0 GHz microscan receiver. This GFE receiver, built by SRI for ECOM under an earlier contract, sweeps its 1.0 GHz band in 1.5 μsec, with 0.3 μsec required for retrace. For the HELMS radar test only the 5.0 - 5.5 GHz portion of the band is used. However, the translator's bandpass filter may be removed and the 16.5 to 17.5 GHz band may be covered, utilizing the microscan's entire 5.0 - 6.0 GHz band, provided that care is taken in interpreting the data gathered. Removal of the filter makes imaging problems likely.

VIDEO output from the microscan receiver is connected to a processor whose threshold is crossed when a -68 dBm signal is present at the microscan receiver's input terminal. When the full 46 dB of RF gain in the translator is used a 10 dB pad must be inserted at the microscan input to prevent triggering on noise. This translates to a threshold corresponding to a -107 dBm input signal level to the translator, relative to an isotropic receiving antenna.

SYNC output from the microscan is used to (1) synchronize the display scope, (2) generate a ramp in the processor for a raster display of received frequency. Circuitry in the processor generates a Z-axis intensification pulse each time a signal from the microscan crosses the threshold. Lockout circuits preclude processor response to more than one signal per microscan sweep; i.e., the first signal of each sweep is the one that is processed. The intensified pulses result in a display similar to Fig. 1, a display of frequency (vertical) vs. time (horizontal).

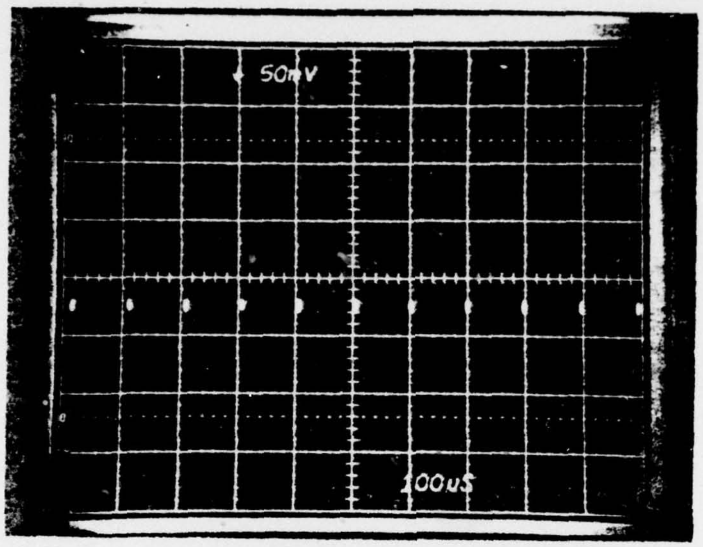


FIGURE 1

Raster display of received frequency vs. time. Represented is pulsed signal at 16.75 GHz with 10 KHz PRF.

The second scope channel produces an A-scope display of the VIDEO pulses coming from the microscan receiver. A rough estimate of received signal power may be made from the magnitude of these pulses.

The last output from the processor, "FREQ OUT", is designed for connection to a strip chart recorder or relatively low-bandwidth oscilloscope. This output provides the same information as the RASTER display, but a HOLD control provides an adjustable duration "pulse stretcher". This allows the observer to determine the signal pulse width, PRI or scan duration (depending on the hold time), and the approximate up and down times of a signal.

II. Operating Instructions

A. Equipment

1) Oscilloscope: Tektronix 7904 mainframe with the following plug-ins:
   a. Two ea 7A19 vertical amplifiers
   b. One ea 7B92 dual time base

2) Strip chart recorder

3) 5.0 to 6.0 GHz microscan receiver

4) 16.5 to 17.0 GHz translator with tripod

5) Microscan processor in Tektronix-type plug-in (with backplane socket wired for supplying power when used external to a Textronix 7000 Series Oscilloscope)

6) Low-pass filter/500 MHz trap in Pomona Box

NOTE: Items 1) and 2) are SRI property supplied to ECOM on one month loan; item 3) is GFE from ECOM.

B. Initial Set-Up

1) Oscilloscope - Processor Wiring
Plug the two 7A19 amplifiers into the left side "VERTICAL" compartments in the mainframe. Plug the 7B92 time base into the left-hand "HORIZONTAL A" compartment, and plug the processor into the remaining "HORIZONTAL B" compartment. Connect processor "VIDEO IN" terminal to the "VIDEO OUT" port of the microscan receiver with 50 ohm cable. Connect processor "VIDEO OUT" to Vertical Channel A. Connect "RASTER" to Vertical Channel B. Use 50 ohm cables. Attach a BNC "T" adaptor to the 7B92's "EXT MAIN SYNC" port. Connect a short cable from the "T" to the processor's "SYNC IN", and connect the other side of the of the "T" to the microscan receiver's "SYNC OUT" port. Connect the processor's "FREQ OUT" port to the strip chart recorder. This output is terminated in 422 ohms, which yields a 1.0 volt full-scale indication when connected to a high input-impedance indicator. DO NOT adjust the recorder sensitivity or position controls. These have been set at SRI and need no further adjustment.

If desired, a high impedance input, relatively low bandwidth (compared to 500 MHz) oscilloscope can be used instead of the chart recorder. If one of the 7A19 plug-ins (50Ω impedance) is used to display the output, connect the LPF/500 MHz trap to the "FREQ OUT" port, and connect the trap's output to the scope with a 50Ω cable. Full-scale deflection will be approximately 25 mv.

2) Control Settings

a. Processor: FREQ HOLD TIME
RANGE: msec x 100
VERNIER: full CCW (point at "2")

b. Oscilloscope:

1. Mainframe - POWER: ON
VERTICAL MODE: B
HORIZONTAL MODE: A

2. 7B92 - use MAIN TRIGGERING SECTION
   MODE: NORM
   COUPLING: DC
   SOURCE: EXT
   SLOPE: +

3. 7A19 (left) - VOLTS/DIV: 0.2
   POLARITY: UP (for negative going pulse amplitude)
   COUPLING: DC

4. 7A19 - (right) - VOLTS/DIV: 50 mv
   POLARITY: INVERT
   COUPLING: AC-GND

3) Operation: Apply power to scope, microscan receiver and translator. Allow 10 minutes for warm-up. Adjust the 7B92 trigger level so the horizontal sweep is triggered. Set TIME/DIV to 100μs/div. The display should be a solid line on the screen. Center this line on the first graticule line above the center line, as in Fig. 2.

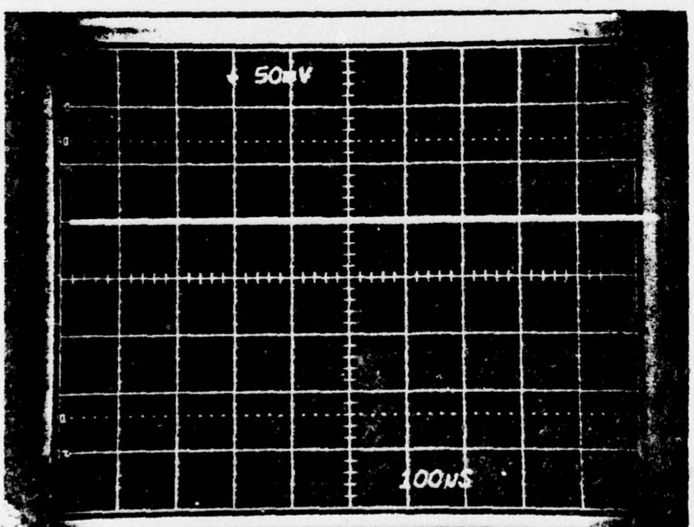


FIGURE 2

Initial location of beam to maintain processor calibration.

Set the B channel from AC-GND to AC coupling. The raster will now be calibrated as in Fig. 3. Each major division on the vertical axis will denote a frequency change of 100 MHz. Decrease intensity so the raster can just not be seen.

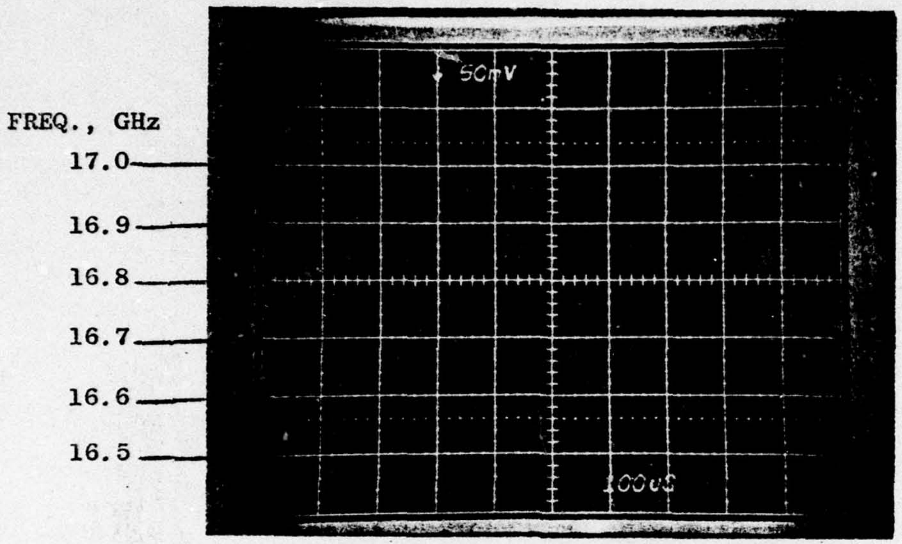


FIGURE 3

Calibration of graticule for raster display vertical scale: 1 cm = 100 MHz.

The translator is shipped with both amplifiers connected. Therefore, connect a 10 dB pad to the microscan receiver's input to keep the processor from triggering on noise. Connect a 50 ohm cable between the translator output and this pad. Adjust the tripod mounting to match the polarization of the signal source and aim the horn antenna at the transmitter. If the signal is strong enough the operator should see intensified dots on the screen indicating the signal's frequency. Horizontal sweep speed may be varied as necessary to provide the type of display desired. For the HELMS Test, where frequency-hopping may occur up to five times per second, 200 ms/div provides a sequence of 1 cm bars which traces the radar frequency for the observer. If no frequency hopping occurs, faster sweep speeds allow the observer to display a solid line indicating the received frequency, and even faster sweep speeds (triggered internally from the left vertical plug-in) will allow observation of the radar's PRI.

To observe an "A-scope" presentation of individual pulses, change to the left vertical channel. Set TIME/DIV to 100 ns/DIV, and VOLTS/DIV to 10 mv/DIV. Increase intensity sufficiently to make the baseline visible and, with the horizontal position control, position the left-most "-20 mv" level of the noise two minor divisions to the right of the left-most border of the graticule (see Fig. 4). The graticule is now calibrated horizontally in frequency as shown in Fig. 4. Set VOLTS/DIV to 100 mv/DIV. A representation of a signal received at 16.75 GHz is shown in Fig. 5. If the pulse magnitude is greater than 700 mv the microscan receiver's amplifiers are limiting, and the operator should reduce the translator's gain, if linear operation is desired.

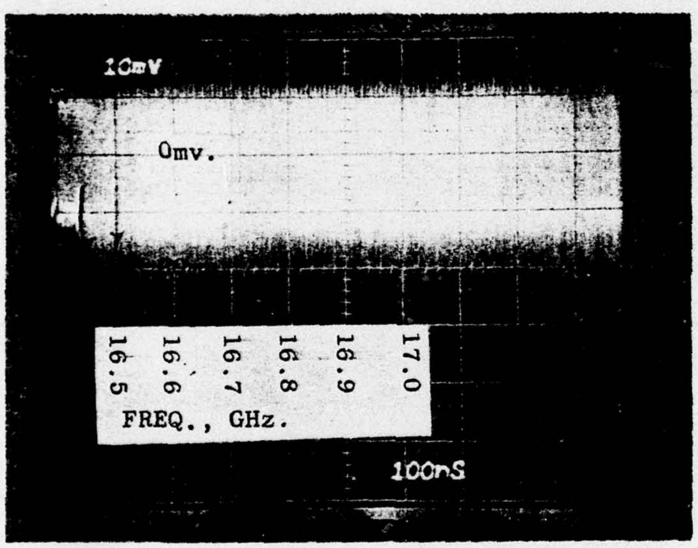


FIGURE 4

Set-up and calibration of A-scope display. Horizontal scale; 1 cm = 100 MHz.

Semi-rigid coaxial cables are supplied to allow gain change by deletion of one or both of the 23 dB amplifiers in the translator. The translator is shipped with both amplifiers connected. To halve this gain disconnect the two cables labelled "46 dB" and connect the cable labelled "23 dB" from the waveguide-to-coax adapter to the input of the top Tunnel Diode Amplifier. For 0 dB gain remove all "23 dB/46 dB" cables and connect the "0 dB" cable from the adapter to the input of the mixer. When the pulse amplitude is less than 700 mv the input to the microscan receiver may be estimated from Fig. 6.

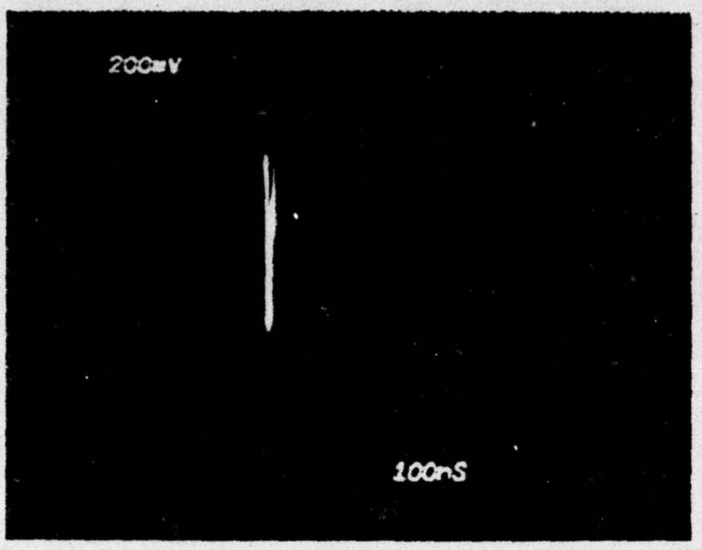


FIGURE 5

A-scope display of 16.75 GHz signal at approximately -50 dBm input to microscan.

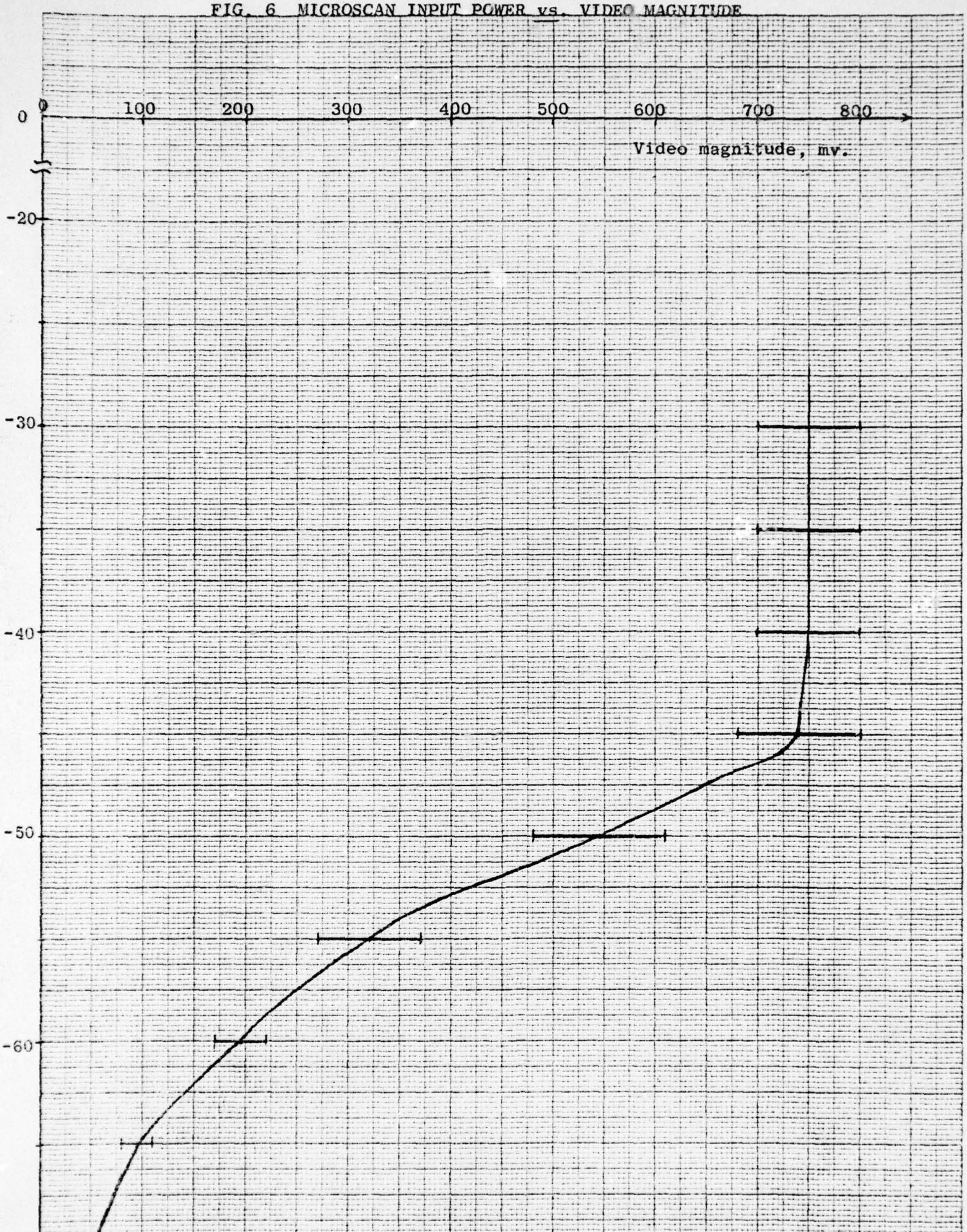
Subtract the following from numbers obtained from the graph for the various translator gains to calculate equivalent power into the translator relative to an isotropic antenna:

Amplifiers	Subtract
both + 10 dB pad	42 dB
one w/o 10 dB pad	29 dB
with 10 dB pad	19 dB
none w/o 10 dB pad	6 dB
with 10 dB pad	(add) 4 dB

For example, a 0.19 volt pulse corresponds to a -60 dBm input to the microscan. With both amplifiers in use the actual received signal strength would be (-60 -42)dBm = -102 dBm referenced to an isotropic antenna.

We turn our attention to the strip chart recorder. As supplied the recorder is calibrated as in Fig. 7. No further adjustment should be necessary. DO NOT perform the Techni-rite calibration procedure as the calibration of Fig. 7 will be lost.

FIG. 6 MICROSCAN INPUT POWER vs. VIDEO MAGNITUDE



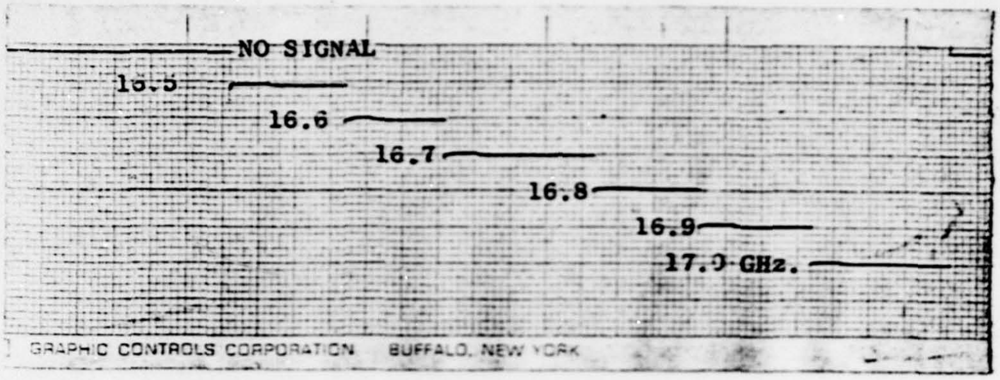


FIGURE 7

Calibration of strip-chart recorder supplied on loan by SRI. Vertical scale: 1/2 cm = 100 MHz.

Controls should be set as follows:

Trace:	DO NOT ADJUST
Sensitivity:	DO NOT ADJUST
Position:	DO NOT ADJUST
Range:	0.20
Chart Speed:	High (2 mm/sec)

If the stylus bounces back and forth between the "no signal" position and some frequency, the FREQ HOLD TIME in the processor is set too short.

The shorter HOLD times (μsec ranges) prove useful when the observer wishes to examine a signal on a pulse-by-pulse basis. An oscilloscope or extremely fast chart recorder (Visicorder) is required, but the FREQ HOLD TIME may be set so the processor resets FREQ OUT after each pulse or group of pulses. Pulse width, PRI or scan duration may be thus determined by selecting the appropriate HOLD time.

III Functional Description-Processor

The microscan receiver output consists of two signals, a video output pulse, VIDEO, and a synchronization pulse train, SYNC. Referring to the block diagram (Fig. 9), the VIDEO signal is fed into a dual threshold PEAK DETECTOR. The trailing edge of the detector output occurs 15ns $\pm$ 5ns later than the VIDEO pulse peak over a dynamic RF input range to the microscan of -68 dBm to -20 dBm. Detection of a VIDEO pulse resets the MULTI-SIGNAL LOCKOUT so the detector will respond to only the first (lowest frequency) signal per receiver sweep.

A detected pulse may be displayed on the oscilloscope with only the pulse intensified (A-scope display). An INTENSIFICATION PULSE, delayed a time equal to the time delay of the oscilloscope vertical amplifier and Tektronix 7904 mainframe, is used to brighten the oscilloscope beam for the time the VIDEO pulse is present.

The frequency of the received signal may be determined by displaying a raster which is generated by the RAMP GENERATOR. Fig. 8 shows an expanded view of the raster with intensified spots indicating reception of a signal (recall Fig. 1 which shows the scope face with a raster display of a signal with 10 KHz PRF). The sweep speed of Fig. 1 is slow compared to Fig. 8 to allow observation of the signal's PRF. The sweep speed used in Fig. 8 could be used to determine the pulse width of signals with pulses longer than 1.8 μsec. The vertical position is proportional to received signal frequency; calibration was shown in Fig. 3.

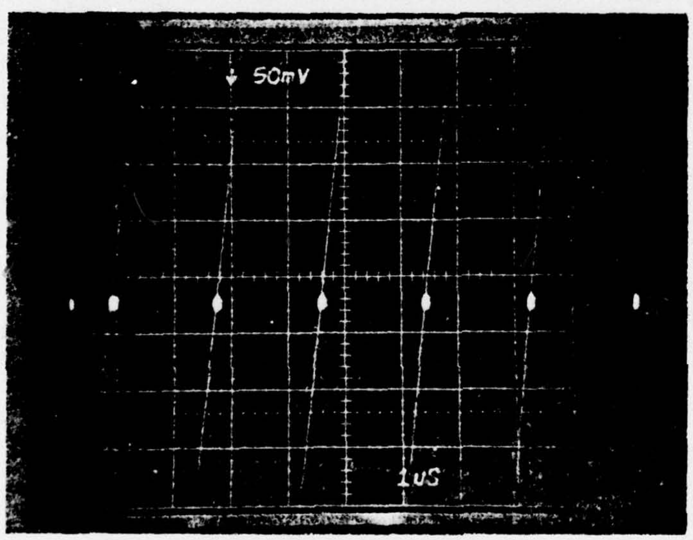


FIGURE 8

Raster display showing voltage ramp and intensified spots indicating detection of a signal. Scope intensity is normally reduced so the ramp is invisible.

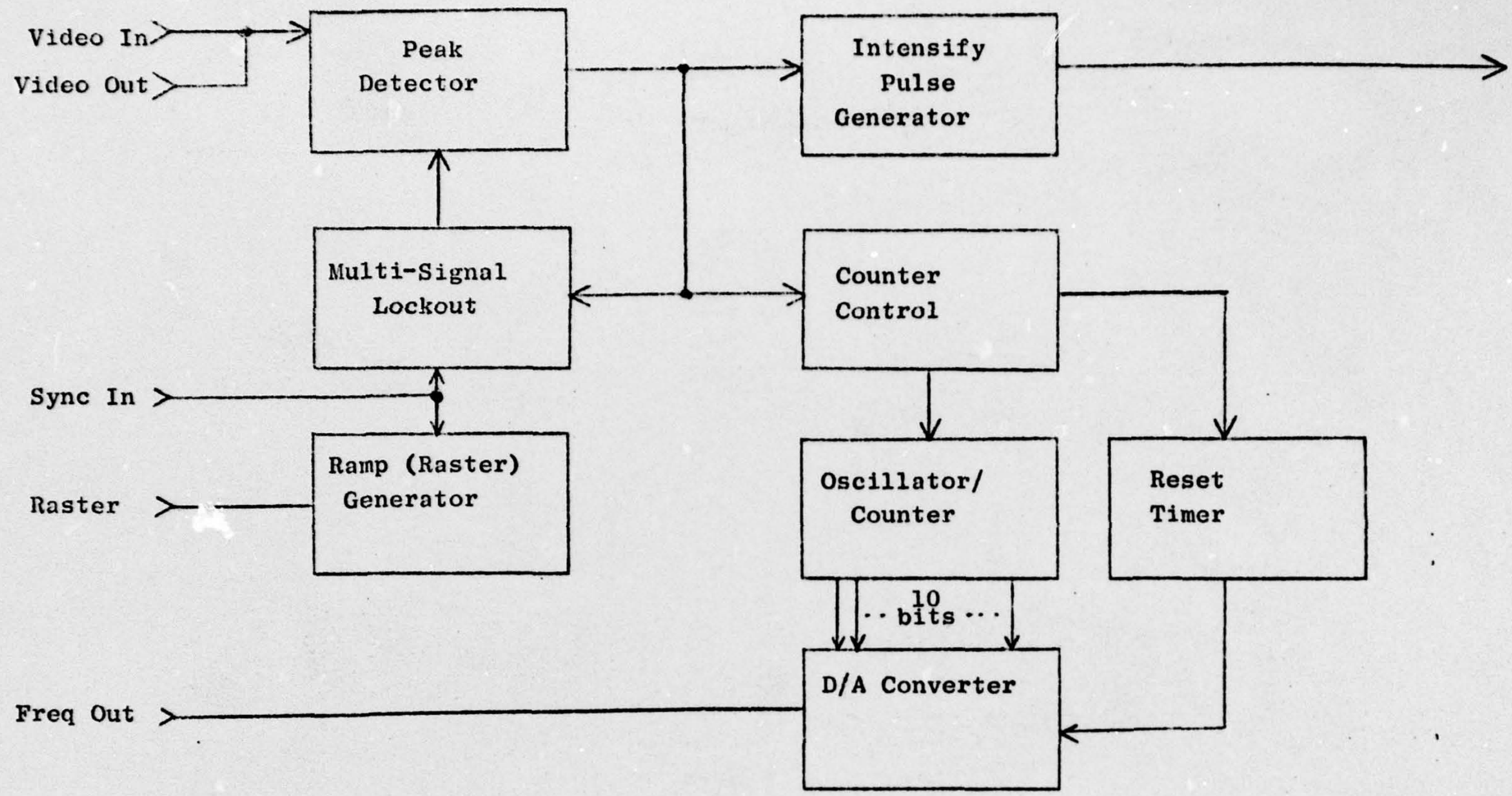


FIG. 9
PROCESSER BLOCK DIAGRAM

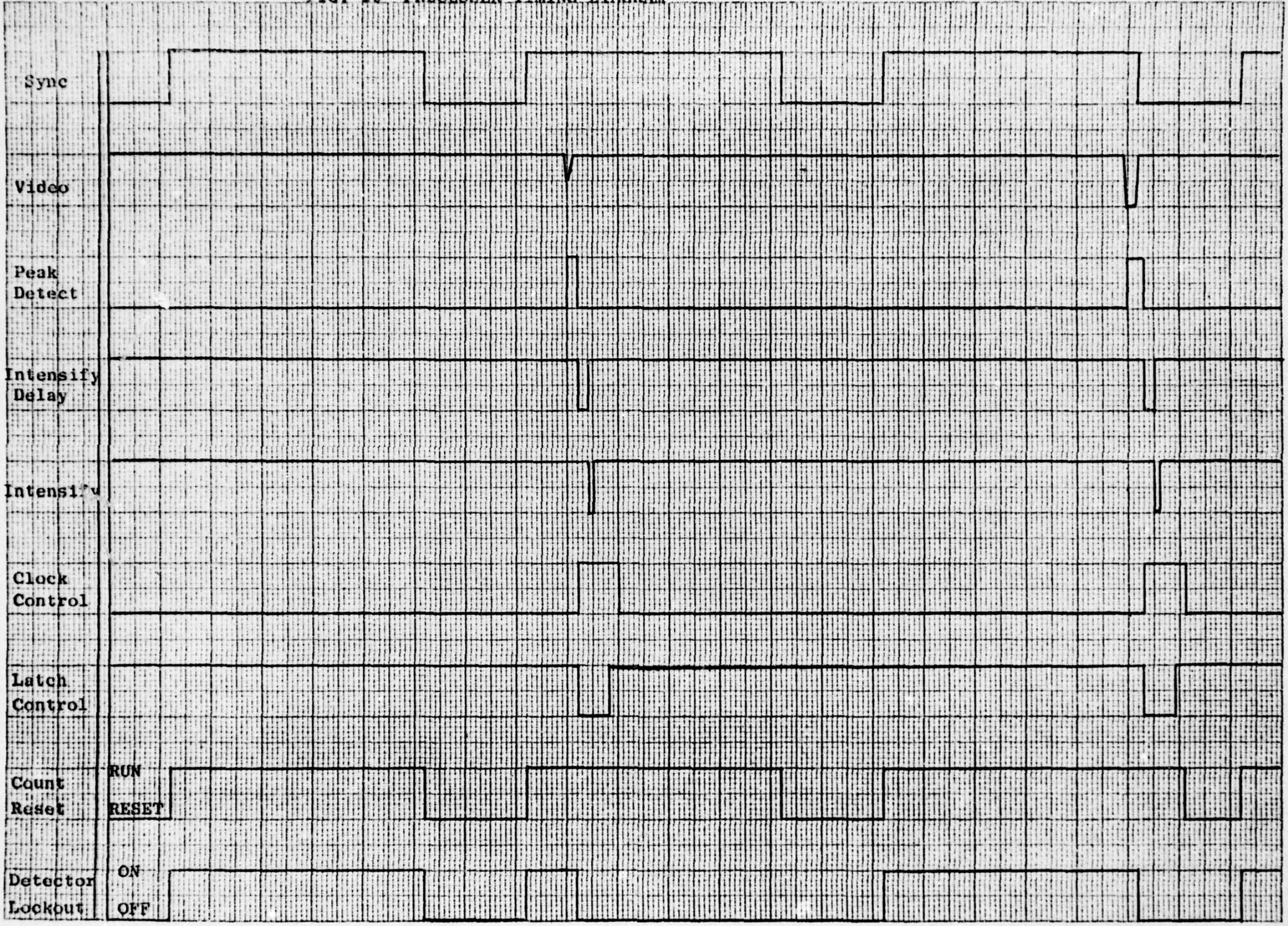
Circuitry is provided to permit a strip chart record of frequency and timing information. A HIGH SPEED COUNTER is started at the beginning of the sweep and stopped when a signal is detected. The binary state reached by the counter is proportional to received frequency, and a D/A CONVERTER provides an output current proportional to frequency. Control circuitry is included to ensure proper sequencing of the counter and a variable delay RESET TIMER is provided to allow the operator to hold the "last received frequency" for any time from 2 μsec to 20 sec. (The HELMS radar test would probably use 200 ms to hold the last frequency for one rotor rotation period.) This feature allows the use of the processor with low PRF signals and provides an indication of last received frequency as well as approximate signal up and down times. If a relatively low-bandwidth scope is used, a signal may be examined on a pulse-by-pulse basis for pulse width, PRI, or scan duration, simply by setting the reset timer to the desired hold time.

IV Operating Principles (Processor-see schematic, Fig. 11, and timing diagram, Fig. 10)

A. Peak Detector

The peak detector is a dual threshold circuit made up of comparators U1A and U1B and one-shots U2A/C and U3A/C. The two one-shots' periods are 15 ns. The thresholds of U1B and U1A are set at VIDEO levels corresponding to signal strengths of -68 dBm and -50 dBm, respectively. The rise time of the leading edge of the negative-going VIDEO pulse is such that as the signal increases from -68 dBm to -50 dBm, the "-68 dBm point" occurs approximately 5 ns earlier than its peak. For low level signals U1B is triggered at -68 dBm (which is close to the peak) firing U2A/C. U2B's trailing edge, delayed 15 ns from the peak, indicates a signal has been detected. At -50 dBm, U2B's trailing edge will be only 10 ns delayed from the peak. However, at -50 dBm U1A is triggered, firing U3A/C. Since U3A and U2A are OR'ed in U2B, the trailing edge of the "detect" signal will again appear 15 ns after the VIDEO peak. As the signal level increases the peak shifts away from the -50 dBm point, until at -20 dBm, U2B's trailing edge is delayed only 10 ns from the peak. The peak detector thus provides an output which is at a nearly constant delay from the signal peak rather than providing an output which merely signifies the occurrence of a threshold crossing.

FIG. 10 PROCESSER TIMING DIAGRAM



B. Intensification

In order to provide a visual display of received frequency, the oscilloscope beam must be brightened only when a signal is detected. The peak detector output is used to fire one-shot U3B/U9B, which delays the intensification pulse approximately 50 ns. This delay, along with the delay in the peak detector, equals the delay in the 7A19 vertical amplifier and 7904 mainframe. U9B's trailing edge fires 15 ns one-shot U9A/C, which provides the actual intensification pulse. The pulse is applied to the CRT at the same time as the VIDEO pulse. In the "raster" mode the intensification pulse, in conjunction with the voltage sweep of the raster, provides a brightened trace whose position on the screen indicates received frequency.

C. Ramp (Raster) Generation

The raster display consists of many consecutive voltage ramps generated by U21A, B and U22. The ramps occur continuously and an indication of frequency is made by the intensification pulse when a signal is detected. The point on the ramp where the intensification occurs, and hence the height of the spot above the baseline, corresponds to the received frequency.

One-shot U21B is triggered by the falling (trailing) edge of the microscan's SYNC output. U21A is likewise triggered by U21B's trailing edge. U21B thus serves as a delay for the beginning of the ramp. When U21A fires, Q1 turns on, which turns on Q2 and discharges the 250 pf capacitor in U22's feedback loop. When U21A turns off, so do Q1 and Q2, and the integration begins. The 10K Ω pot connected to U22's inverting input determines the slope of the ramp and its length before saturation. The circuit is more stable if the input voltage is slightly positive. The resulting ramp has a negative slope due to the inverting operational amplifier, which necessitates inverting the oscilloscope channel used for the raster mode.

D. Transistor Q3 and associated circuitry comprise a free-running 500 MHz oscillator whose output is padded down and D. C. level shifted to provide an ECL-compatible 500 MHz input to U10. U10 through U16 make up a 10-bit counter whose "word" magnitude is proportional to received frequency. SYNC from the microscan holds the counter at "0" until the start of a microscan sweep. If no signal is detected during the sweep, the counter is reset and held at "0" until the next sweep. If a signal is detected, the peak detector fires one-shots U4/U8A and U5/U6. One-shot U5/U6, of 100 ns period, stops the counter with U6A's output. U6B's output

NOR's the SYNC and U5's 100 ns pulse so that counter reset is held off if an invalid signal is detected at the extreme upper end of the band (during the microscan receiver's "retrace" period). U4/U8A, of 80 ns period, clocks the state of the stopped counter into latches U17 and U18 with its trailing edge. The 80 ns pulse allows all the ripple-down clocks in the counter to come to rest before the counter state is latched. At the end of U5's pulse the clock is restarted. When U6B's output goes high the counter is reset.

Latches U17 and U18 are connected to D/A converter U19, whose output is a current proportional to the 10-bit word on its inputs. As long as VIDEO pulses are received at intervals shorter than the time set on the reset timer, the latches are not reset, but are simply presented with a new counter state each time a VIDEO pulse is detected. If the reset interval is exceeded the reset timer puts out a 100 ns pulse which resets the latches and D/A output. The reset interval is continuously variable from 2μs to 20 sec.

E. Multi-Signal Lockout

U20A/B form a latch which enables the peak detector at the beginning of the SYNC pulse. If no signal is detected during the sweep, SYNC disables the comparators during the retrace. If a signal is received, U4B's output resets the latch, disabling the peak detector and preventing more than one pulse from affecting the output circuits.

F. Start-Up Sequence

The -5V power for the ECL circuits is derived from the +15V and -15V supplies through a DC-to-DC converter. There is a 5μf capacitor across the converter input, making possible a large in-rush current upon start-up which might damage the oscilloscope. This possibility necessitates start-up circuit consisting of Q4 - Q6, RY1 and associated components. When power is first applied, Q4 and Q6 are off and Q5 is on. RY1 is open and there is a 47 ohm resistor in series with the DC/DC converter to precharge the input capacitor. Approximately 2 seconds after start-up, when the 220μf capacitor in Q4's base is charged, Q4 turns on, turning off Q5 and turning on Q6. RY1 operates, by-passing the 47Ω resistor, and normal converter operation begins.

G. Timing Diagram

Fig. 10 shows the sequence of operation for three sweeps of the microscan receiver. The VIDEO signal shows a sweep with no signal, a sweep with a pulse corresponding to a signal strength between -68 dBm and -50 dBm, and a pulse corresponding to a signal strength greater than -50 dBm. The two pulses show how the peak detector pulse's trailing edge occurs a nearly constant time after the signal peak.

INTENSITY DELAY is the pulse from one-shot U3A/U9B.

INTENSIFY is the pulse from one-shot U9A/C.

CLOCK CONTROL is the 100 ns pulse from U6A.

LATCH CLOCK is the 80 ns pulse from U8A.

COUNT RESET is the output pulse from U6B.

DETECTOR LOCKOUT is the output of the multi-signal lockout cicuitry.

V. Translator Block Diagram - see Fig. 12

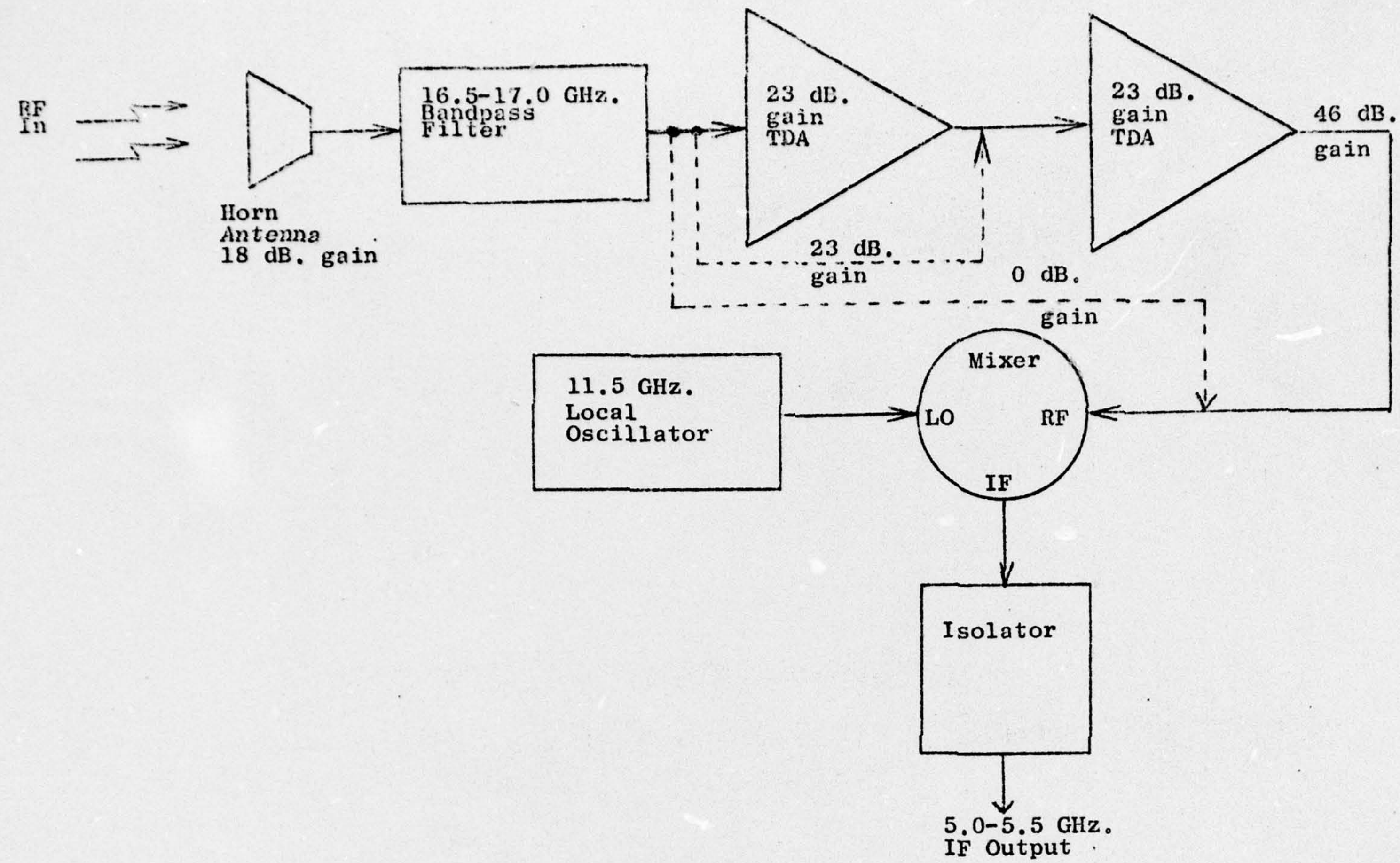


FIG. 12
TRANSLATOR BLOCK DIAGRAM